unexpected places, and passengers in a train may feel a shock because a charge has struck the rails. In powder-magazines it is apparent how dangerous this lawless sparking tendency may be; for even the hinge of a door may furnish opportunity for some trivial spark sufficient to ignite powder. By no means should high rods be stuck up to invite a flash to such places. Build them, or line them, with connected iron, barb them all over the roof, connect them to the deep ground in many places, and but little more can be done.

These electrical oscillations and overflows, which it is easy to set up in a charged conductor, manifestly explain what is known as the 'return-stroke.' This fact — that a discharge from any one point of a conductor may cause such a disturbance and surging as to precipitate a much longer flash from a distant part of it — at once accounts for any 'return-stroke' that has ever been observed.

It is for this reason that it is possible that a tall chimney or other protuberance in one's neighborhood may be a source of mild danger; inasmuch as if it is struck it may be the means of splashing out some more discharges to other smaller prominences, which otherwise were beyond striking distance.

Finally, is it possible for the interior of a thoroughly enclosed metal room to be struck; or, rather, can a small fraction of a lightning-flash find its way into a perfectly enclosed metal cavity, for instance, a spark strong enough to ignite some gun-cotton in a metal-covered magazine which might happen to be struck?

The application of the laboratory experiments to powder-magazines is, that, if any conductor (like a gas-pipe) pass out of the building before being thoroughly connected with its walls, it is possible for a spark to pass from something in the interior of the building to this conductor whenever a flash strikes the building.

The complete and certain protection of buildings from lightning is by no means so easy a matter as the older electricians thought it. In many cases we may be content to fail of absolute security, and be satisfied with the probable safeguard of a common galvanized iron rod or rope. But for tall and important buildings, for isolated chimneys and steeples, and for powder-magazines, where the very best arrangement is desirable, what is one to recommend? Professor Lodge sees nothing better than a number of lengths of common telegraph-wire. He thinks a number of thin wires far preferable to a single thick one; and their capacity must be increased when possible by connecting up large metallic masses, such as lead roofs and the like. But the connection should be thorough, and made at many points, or sparks may result. Balconies, and other prominent and accessible places, should not be connected.

The earth should be deep enough to avoid damage to surface-soil, foundations, and gas and water mains. As to the roof, he would run barbed wire all round its eaves and ridges, so as to expose innumerable points, and the highest parts of the building must be specially protected; but he would run no rods up above the highest point of the building, so as to precipitate flashes which else might not occur, in search for a delusive area of protection which has no existence.

The conductors must not be so thin as to be melted or deflagrated by the flash; but melting is not a very likely occurrence, and, even if it does occur, the house is still protected. The discharge is over by the time the wire has deflagrated. The objection to melting is twofold: first, the red-hot globules of molten metal, which, after all, are not usually very dangerous out of doors; and, second, the trouble of replacing the wire. The few instances ordinarily quoted of damage to lightning-conductors by a flash do not turn out very impressive or alarming when analyzed.

MENTAL SCIENCE.

The Nature of Muscular Sensation.

THE active side of psychic life is represented by movements. The study of the ways and means by which these movements are brought about, are co-ordinated and directed to useful ends, forms one of the most important chapters of physiological psychology; but the elements that enter into conscious motion are so numerous, and so intricately connected, that our knowledge of the process is as yet very defective. It has been well said that the clear and definite statement of a problem is a long step towards its solution. While recent research has not succeeded in definitely explaining the nature of the sensations connected with movements, it has cleared the problem of many misconceptions which had attached to it, and called attention to those points from which a final solution may be expected. M. Binet has recently brought together the various aspects of the problem, and added thereto an ingenious suggestion towards their further elucidation (*Revue Philosophique*, May, 1888).

The first distinction that M. Binet emphasizes is that between the consciousness of a movement and that of the co-ordination of the muscles necessary to make it. The latter does not enter into the psychic aspect of movement at all. We may be, and usually are, unaware of the simultaneous and orderly contraction of the various muscles necessary to perform a useful act, and yet be perfectly able to do the act. It is the mental conception of the finished act that guides the muscles and gives unity to the movement. Our problem deals only with the methods by which we become aware that our muscles have obeyed the mandate of our will.

The simplest source of such knowledge is that obtained through the eye. We know that a movement has been accomplished, because we see it. Again, in speaking, we know that the muscular mechanism of articulation has acted properly, because we hear the resulting sound. The voices of speaking deaf persons are usually harsh, owing to the lack of the corrective power furnished by the ear. But, even with the eyes closed, we have quite a definite knowledge that the desired movements have been performed. The general sensibility, the feeling of effort as shown in the change of respiration, etc., the dermal sensations produced at joints, and the feeling of the shortening of muscles, — all contribute to the result. We are powerless to analyze the several *rôles* played by these factors by observing actions in ourselves; but here pathology helps us out of the difficulty, and shows what psychic factor is deranged when a physiological function is lost, as will be touched upon later. Again, this latter class of sensations can learn to control movements which at first require the aid of vision. Walking is a conspicuous example of such. All these factors have the one point in common, that they act after the muscles have contracted. They are due to impressions proceeding inwardly, centripetally, to the brain, and thus informing us what has been done.

The question has been raised, however, whether we have not knowledge of movement centrifugally before the action takes place; whether we have not an outgoing feeling of expended energy suited to the act in question. This view has been supported by many illustrious names, and it has been negatived with equally good authority. The objectors call attention to the fact that there is such a thing as a motor image formed from former sense-impressions, and that this is sufficient to call up the proper mental antecedent upon which the motion ensues. This tells us how much energy to discharge, leaving the rest of the factors to take effect when the action is done.

Pathology calls attention to cases in which the tactile sensibility is destroyed, hoping to draw important conclusions from the interference that this causes with voluntary movement. When such a patient performs a movement, he has only the visual sensory image to guide him; and, if this be taken away by blindfolding him, what will happen? This is the important test; but it is not unambiguous in its interpretation. Most patients will do an action at command with their eyes closed nearly or quite as well as with their eyes opened, the movements in question being those of an anæsthetic limb. They write with the feelingless hand as well as normally. From this observation we can at once conclude that the power of co-ordinating movements, and the consciousness of the motion, are two different things; for these same patients can have their limbs moved for them without their knowing it, thus showing that the centripetal part is interfered with. Another class of patients, however, are reduced, by closing their eyes, to a condition of almost complete motor impotence. In spite of persistent exhortations, they cannot take one hand in the other, touch their forehead, and so on. The upholders of one side of the question emphasize the former result, arguing that the centripetal sensations are not sufficient to direct motion (for here they are lacking), and thus show the necessity of assuming a consciousness of outgoing energy, an

innervation feeling. Their opponents point out that with the loss of sensibility goes the loss of power to move, making an innervation feeling unnecessary. How can these two classes of facts be reconciled and brought under one law?

In answer to this query, M. Binet has a useful suggestion to offer. It has been shown that among hysterical patients with anæsthetical regions a physical or psychic stimulus increases motor power; acts dynamogenetically, as Féré puts it. May not the opening of the eyes act in the same way with some patients, and this re-enforcement be unnecessary with others? In support of this view is the observed fact that in a patient whose right arm was anæsthetic, and who could not move this arm as desired with her eyes closed, this closure of the eyes had a like effect upon the sound left arm. In both cases the movements were slow, inexact, hesitating, more so with the diseased arm. Intermediate cases occur in which the withdrawal of the eye weakens the power of movement without destroying it, thus showing the characteristic individual variations of this re-enforcing power. Moreover, the movements of anæsthetic limbs have, according to M. Binet, been wrongly interpreted. Although such patients are unaware of passive movements, yet these are physiologically registered in their nervous system. This is shown by the fact that a movement thus passively made by guiding the patient's hand will be reproduced by her voluntarily. She does not know what motions have been made with her hand, but her brain-cells reproduce the same motions. We must admit that movements can be voluntary without being conscious. In conclusion, M. Binet gives the opinion that the supposition of a feeling of innervation acting centrifugally is as yet an ungrounded one, and expects much light from future research.

MEMORY OF MOVEMENTS. — In the *Revue Philosophique* for May, Professor Beaunis describes an interesting series of experiments upon the memory of muscular movements. The experiments form part of a more extended research upon the memory of sense-impressions in general, and are concerned with two questions. The first relates to the accuracy with which the length of lines drawn without the aid of the eyes can be reproduced; the second, to the reproduction of angles under similar conditions. A line is drawn, and, after an interval of from five to fifty seconds, the attempt is made to draw a second line equal to the first, making it with a little stroke to distinguish it from the first. Another method was to make a dot move over a distance and make a second dot; in the reproduction to make a small cross move over an equal distance and make a second cross. In another series two lines were drawn making an angle with one another such as <, and the attempt made to draw another broken line with the same angle. In this test right angles were avoided as being too definite an impression. Care was taken not to have the subject know the results, as this would bring about a more or less unconscious rectification of the errors committed. Professor Beaunis describes his memory as a good one, and mentions that the experiments were made in the evening before going to bed, or when awaking in the night or in the morning, when he was undisturbed by outside noises. The strain of fixing the attention on so minute an impression for more than a few seconds he found very considerable, often inducing feelings of *malaise*. From his observations (to be published in detail later) he draws three general conclusions, confessedly of a tentative character. 1. The memory of the movement does not lapse from consciousness gradually. The memory-image does not fade out little by little, but vanishes more or less suddenly. There is here an analogy with the reverse process, that of recalling a forgotten impression. We have a word on the tip of the tongue, when suddenly it looms into consciousness. 2. When it is no longer possible to recall by a purposive effort the line drawn, — when, for example, one does not even remember whether the angle drawn was acute or obtuse, — the hand will none the less, within a given interval, draw a line closely approximating the original. There is an unconscious memory which in turn loses its accuracy. There is thus a phase of conscious memory, succeeded by a period of unconscious (organic) memory, in turn giving way to a more or less complete forgetfulness. 3. There are sudden variations in the accuracy of the reproductions from one moment to another. These follow no definite law, but are doubtless influenced by variations in subjective conditions.

ELECTRICAL SCIENCE.

Some New Primary Batteries.

AMONG the primary batteries that have lately appeared, two — one an English and one a French invention — deserve special notice. The first of these is an invention of M. Weymersch, and is of the ordinary Bunsen type with zinc and carbon electrodes, the improvement consisting in the employment of a new depolarizing fluid, which greatly increases the constancy of the battery. The Bunsen and bichromate cells give a high electro-motive force; but they are not constant under heavy discharge, the electro-motive force falling considerably. The Weymersch battery, according to some tests published in the London *Electrical Review*, has an almost constant electro-motive force for a heavy discharge extending over a considerable period. For instance: from cells with two zinc plates 6½ by 6⅝ inches, and one carbon plate of the same dimensions, a current of over ten ampères (about 10.3) was taken for thirty-one hours, and at the end of that time the electro-motive force had only fallen a few per cent. The consumption of zinc was only ten per cent more than the theoretical amount, showing that the local action was slight. The inventor proposes to use the battery for the lighting of country houses on a small scale, for torpedo-work, miners' lamps, etc., besides the ordinary uses to which closed-circuit batteries are now put. He calculates that electric lamps aggregating 45-candle power can be supplied for six hours at a cost of eighteen cents per day. Whatever uses it may be put to, it is certain that the tests make an excellent showing.

The other cell, an invention of Mr. O'Keenan of Paris, has been lately described before the New York Electrical Society by Mr. Alfred Shedlock. It is a simple Daniell element, — zinc and copper electrodes in contact with sulphate of zinc and copper respectively. The invention consists in the means employed to keep the strength of the two solutions constant, and a set of cells is arranged to continuously charge storage-batteries from which lamps are supplied. As the electro-motive force of a Daniell cell is about one volt, while that of the Weymersch cell is two volts, twice as much zinc will be consumed in the former as in the latter for the same amount of energy obtained. Mr. Shedlock states that the cost of the zinc and copper sulphate will be at the rate of about one cent per hour for a 12-candle power lamp. If we add the cost of breakage of lamps, interest on investment, depreciation, etc., it will be found that the total cost is at least double this, and lighting in this way would be expensive.

These two batteries are fair types of the improvements that have been recently made in primary cells. Both of them have a field for usefulness, but neither of them can be economically used for lighting or for heavy motor-work.

INCANDESCENT-LAMP EXPERIMENTS. — The following abstract is from the London *Electrician*: "At a recent meeting of the Société Française de Physique, M. Mascart described some interesting experiments which he had carried out with a view of determining how far incandescent lamps might be a source of danger when in the immediate vicinity of inflammable materials. Some 32-candle power incandescent lamps were tightly enveloped in cloth, others in wadding with the gummed surface removed, and others again were placed in the folds of some old stage-scenery. In no case was there any charring or undue heating. An extra thick cotton hood placed over a 32-candle power lamp became charred wherever it was in contact with the globe after ten minutes had elapsed. A 32-candle power lamp which was surrounded by a black silk hood, and then by a black velvet one, set the latter burning gradually in six minutes. In another experiment two lamps were enveloped respectively in black and white wadding from which the gummed surface had *not* been removed; and in two minutes charring commenced, both lamps burst, and the wrappings were set alight. Finally a 300-candle power lamp was laid against some old scenery: in a minute and a half the scenery began to char where the globe touched it, and slowly burnt without flame."

ELECTRICAL RESISTANCE OF COPPER AT LOW TEMPERATURES. — The following note is from *Engineering*: "M. Wroblewski has undertaken to test the truth of Clausius' remark in 1856, that the electrical resistance of chemically pure metals should be